Mixing and Transport in the Surfzone

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Grant number: N00014-7-1-0377

LONG-TERM GOALS

The long-term goal, better understanding surfzone mixing and transport, would allow improved prediction of the fate of terrestrial runoff pollution and other substances (e.g. fine sediment, chemicals) sometimes present in very shallow water.

OBJECTIVES

Objectives were to 1) participate in analysis of waves and currents observed (NCEX, 2003) near the onshore branch of a submarine canyon, (2) develop methods to measure breaking wave-driven mixing and transport in the natural surf zone, (3) use field observations to test and calibrate numerical models for surfzone mixing and transport.

APPROACH

Wave breaking occurs most of the time on most ocean beaches. Even the most sophisticated numerical models must parameterize the highly turbulent dynamics of wave breaking, and the ensuing cascade of momentum and energy to both large and small scales of motion. Sediment transport adds another layer of theoretical uncertainty to models for wave-driven changes in beach morphology. My general approach is to use field observations to test and calibrate the heuristic numerical models used to model wave-driven beach processes. All aspects of the work, from pre-experiment planning to publication of results, are highly collaborative with students, post docs, and other scientists.

WORK COMPLETED

Waves and currents observed near the La Jolla and Scripps submarine canyons during the ONR/NSF supported Nearshore Canyon Experiment (NCEX) experiment have been analyzed and interpreted (Thomson et al., 2006, 2007; Apotsos et al, 2007a, 2007b, 2008). Methods to observe transport and mixing in the surfzone using water-following drifters (Schmidt et al 2003), and fluorescent dye (Clark et al, submitted) have been developed.

RESULTS

Ongoing work uses dye and drifters as proxies for pollutants, chemicals from ordnance, and other tracers of interest.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **2008**	2. REPORT TYPE	3. DATES COVERED **00-00-2008 to 00-00-2008**
4. TITLE AND SUBTITLE **Mixing and Transport in the Surfzone**		5a. CONTRACT NUMBER
		5b. GRANT NUMBER
		5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER
		5e. TASK NUMBER
		5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Scripps Institution of Oceanography,La Jolla,CA,92093-0209**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR’S ACRONYM(S)
		11. SPONSOR/MONITOR’S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release; distribution unlimited**		
13. SUPPLEMENTARY NOTES		
14. ABSTRACT		
15. SUBJECT TERMS		

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**7**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

Dye Tracer : Newly adapted fixed (frame mounted) and mobile (jet ski mounted, Figure 1) methods for in situ measurementof surfzone fluorescent Rhodamine WT dye were tested in the field and laboratory (Clark et al, submitted).

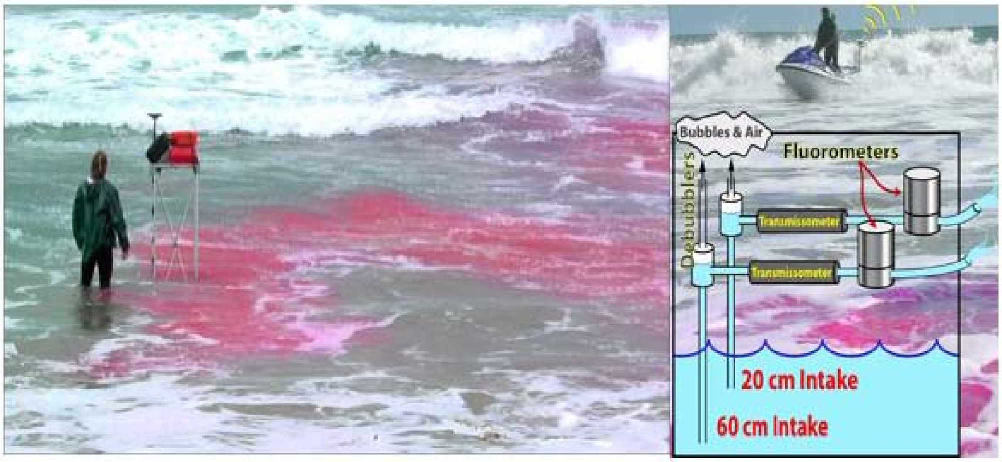

Figure 1 (left)tracer dye injected continuously into the surfzone at a controlld rate forms a plume (right) GPS-tracked,dye-sampling jet ski on a transect across the surfzone. On-board, flow-through dye sampler (inset) includes an electric pump, a debubbler, a turbidity sensor, and a Rhodamine WT dye fluorometer, sampling at 5Hz. To reduce effects of bubbles and sand on the optically measured dye concentration, the jetski is driven in the relatively low turbulence region in front of a bore. A handlebar-mounted screen displays realtime data and a local position map, allowing repeated sampling of pre-determined transects. Position and sensor data are transmitted ashore, allowing real-time analysis and adaptive sampling.

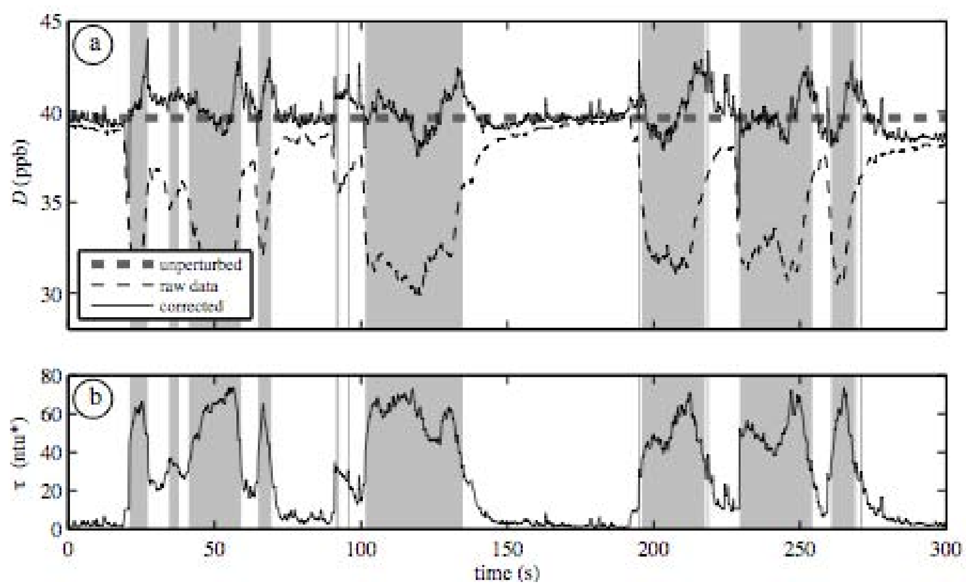

Figure 2: For the jetski-mounted flow through system in the lab, (a) raw (dashed black curve) and corrected (solid black curve) dye concentration D and (b) turbidity T versus time. Bubbles were mixed in filtered seawater with known concentration D = 40 ppb (thick dashed gray line in (a)). Deviations from 40ppb are reduced significantly by correcting for turbidity. In both panels, light gray vertical bands indicate times of high turbidity (T > 30ntu).

Bubbles and sand, suspended by breaking waves in the surfzone, interfere with optical fluorometer dye measurements, increasing the lower bound for dye detection and reducing (quenching) measured dye concentrations. Simultaneous turbidity measurements are used to estimate the level of bubble/sand interference, and empirically correct for quenching. Errors in raw and corrected dye measurements are estimated from lab experiments with known dye concentrations (Figure 2). The system can also sample chlrophyl A (Omand et al, submitted). The dye sampling jetski and fixed fluorometers were deployed at Huntington Beach, as part of the HB06 field experiment. SIO graduate PhD student David Clark, co-advised with Dr Feddersen, is using these observations to characterize surfzone mixing (figure 3).

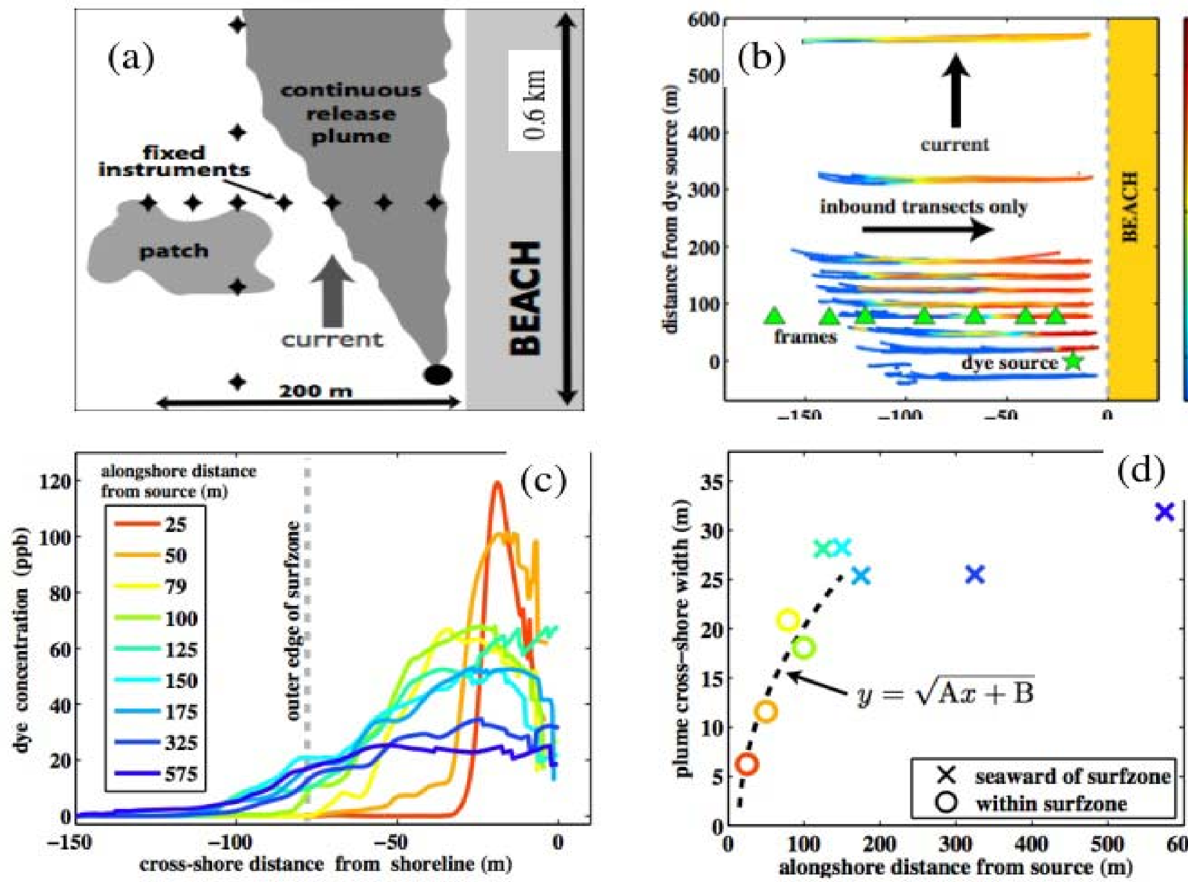

Figure 3: (a) Schematic of HB06 dye plume mixing experiment. Fixed instruments (current meters and pressure sensors) measured waves and currents on cross- and alongshore transects. Dye was measured at (usually) 4 locations with fixed fluorometers, and with a jetski. Dye was released as a single patch, and continuously forming a plume. (b) ski-sampled dye concentrations across a dye plume are indicated by colors (scale to the right). During a 4-hr plume release on 11 Oct 2006, the mean alongshore current near the shoreline was 20 cm/s, and the breaker height was 50 cm. About 10 passes were made along each transect. (c) Dye concentration versus cross-shore distance with colors corresponding to alongshore distance. Far from the source (blue and purple, see legend), the plume is broad and the concentration is low (d) plume cross-shore half- width versus alongshore distance from the source.

Drifters: Water-following drifters (Figure 4) provide an additional method for estimating surfzone transport and mixing. Drifters, deployed on 5 days during HB06 (Figure 5), produce results qualitatively similar to those obtained with dye. For example, the dominant mean transport is by the alongshore drift (Figures 3b and 5). Cross-shore mixing is largely confined to the surf zone; with little dye (figure 3c) and few drifters (Figure 5) leaving the surf zone. In both cases, tracers (dye or drifters) spread rapidly across the surf zone (~50m width, Figures 3d, 6), but futher cross-shore spreading is weak. After 15 minutes, a tracer patch is abut 3 times longer in the alongshore direction than in the cross-shore direction (Figure 6). Aspects of drifter separation statistics suggest that 2D turbulence with a wide range of eddy scales is causing the surf-zone dispersion (Spydell et al, 2007). However, the time dependence of the relative dispersion and the diffusivity's scale dependence differ from 2D inertial-subrange scalings (Batchelor 1950). Thus, the 2D surf-zone eddy field responsible for dispersion is not a classical 2D inertial subrange (an energy cascade). The source of this vorticity-dominated eddy field with length scales 5–50 m vorticity is not understood. Shear waves likely would input vorticity at longer length scales O(100 m) which, for flat-bottom 2D turbulence, would cascade energy to larger length scales—too large to explain the observed 5–50-m scale dependent diffusivities. The source of vorticity (eddies) with scales less than about 50 m may be alongshore gradients in breaking-wave heights (Peregrine 1998) associated with finite crest length (Sdydell et al, 2007).

Figure 4: GPS equipped, water-following drifter in the surf zone. The drifters, that 'duck under' bores and do not surf shoreward, relay their position to shore, allowing real-time tracking.

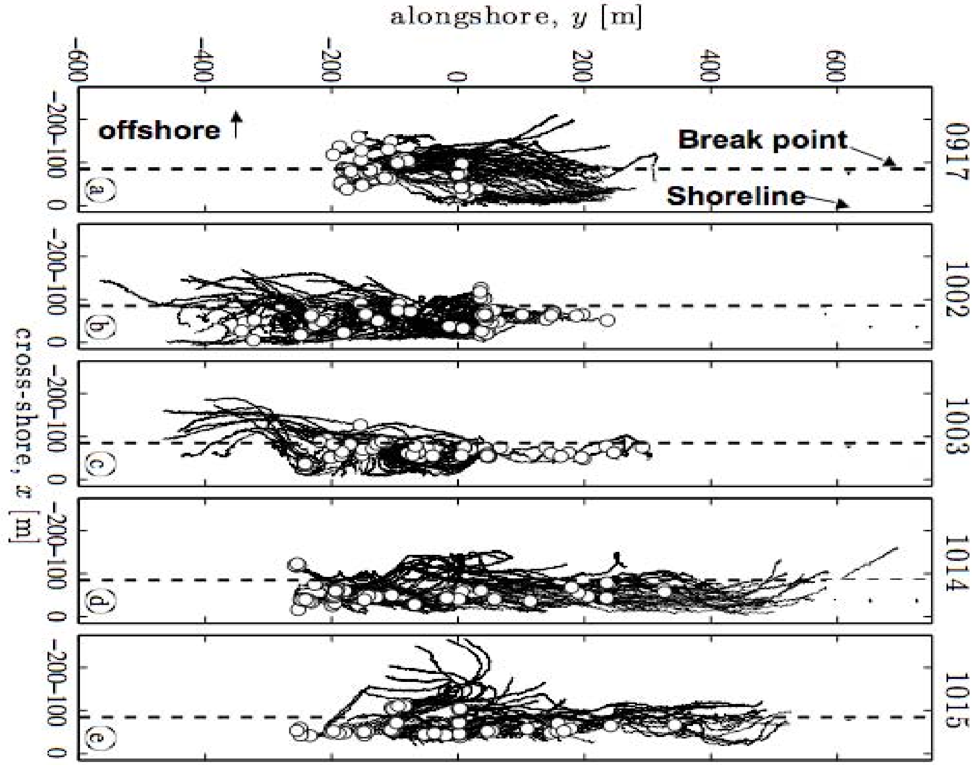

Figure 5: Drifter trajectories (black curves) for 5 days during HB06. Open circles are drifter release locations. Individual drifters moved as much as 600m alongshore, but less than 100m offshore.

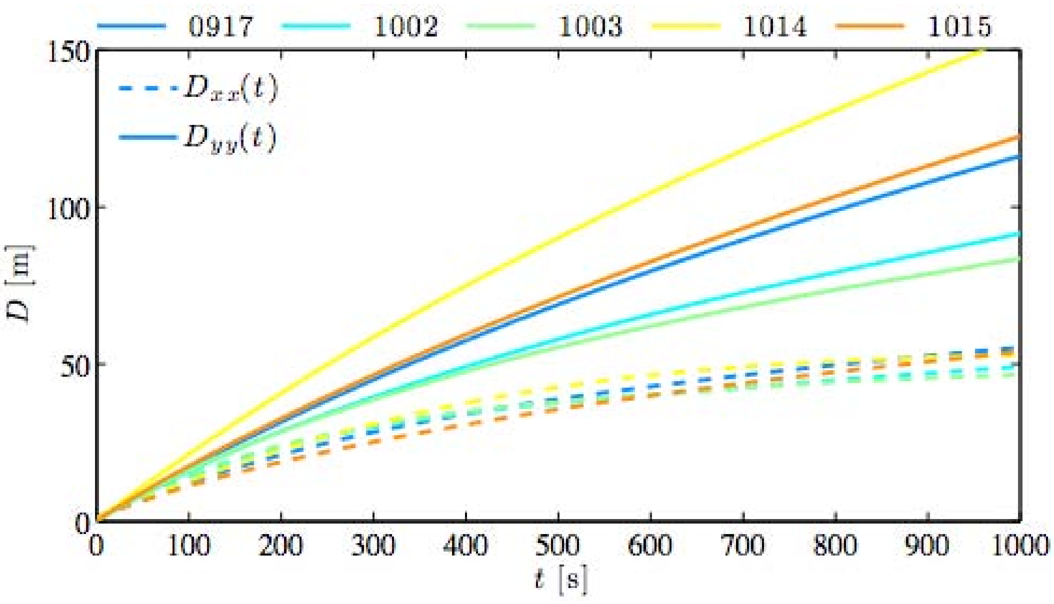

Figure 6: Growth of tracer patch size D versus time, estimated from drifter data. Initially, D=0. Solid and dashed lines are the along-shore (y) and cross-shore (x) patch dimensions, respectively. Colors correspond to different days during HB06 (from Spydell et al, in prep.)

IMPACT/APPLICATIONS

Tracer evolution and transport in the nearshore is important to Navy/Marine objectives including chemically detecting mines, avoiding contact with dangerous substances, and predicting where optical clarity will be effected by fine sediments and silt. A goal is to develop a portable (between sites) model suite that, given bathymetry and incident wave conditions, predicts (perhaps qualitatively) tracer transport and dilution.

RELATED PROJECTS

NCEX observations of surfzone waves and circulation were obtained in collaboration with Drs Elgar and Raubenheimer (WHOI). NCEX data are available to the public on Steve Elgar's website (http://science.whoi.edu/users/elgar/NCEX). Huntington Beach (HB06) observations and analysis are collaborative with Drs F. Feddersen and M. Spydell, and student D. Clark (SIO). HB06 data are available upon request. With continung support from the State of California, nowcasts and forecasts of surfzone waves and alongshore currents at Huntington Beach are available http://cdip.ucsd.edu/hb06/.

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PUBLICATIONS (2007-2008) acknowledging ONR support

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